



Transportable Modular Reactor by Balance of Plant Elimination

Dr. Claudio Filippone

claudio@holosgen.com

Dr. Chip Martin

charles.m@holosgen.com

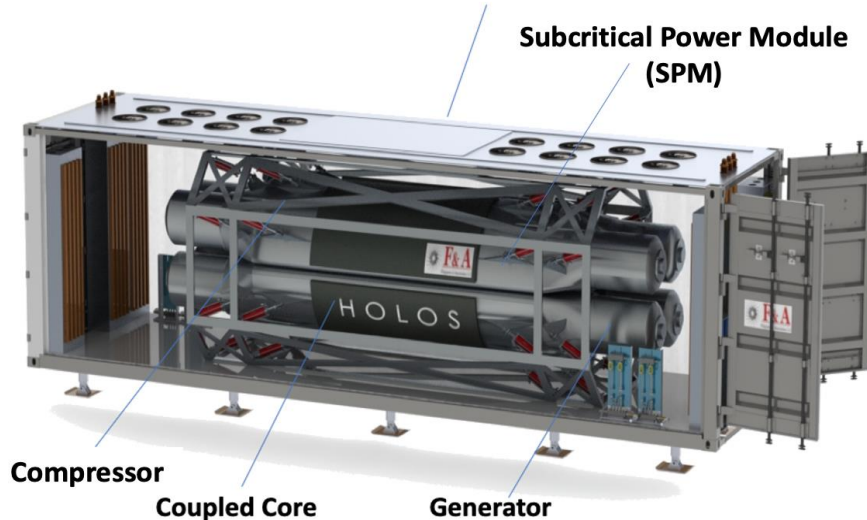
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HolosGenTM

Affordability & Enhanced Safety via Balance of Plant (BoP) Elimination

Project Objectives

Standard ISO container dimensions



- Reduce cost while increasing safety
- Integrate the power conversion system
- Seal the fuel via sleeved core
- Decoupled compressor-turbine
- Individual shielded SPM transport
- Fast response load following
- Factory produced and tested
- Affordable (sensitivity via high-fidelity TEA)

Why This Matters:

- Enables electric power distribution independently of site-specific stressors
- Eliminates nuclear island, turbine island, BoP, and multiple reinforced concrete structures. Integral microreactors represent true economy of scale
- HolosGen paved the way for nuclear vendors and funding institutions to gain confidence in developing microreactors
- Next steps: i) Complete full-scale design and subscale simulator testing and ii) Construct a full-scale non-nuclear SPM to support and accelerate regulatory processes

HolosGen Team

► Team Organization and Responsibilities

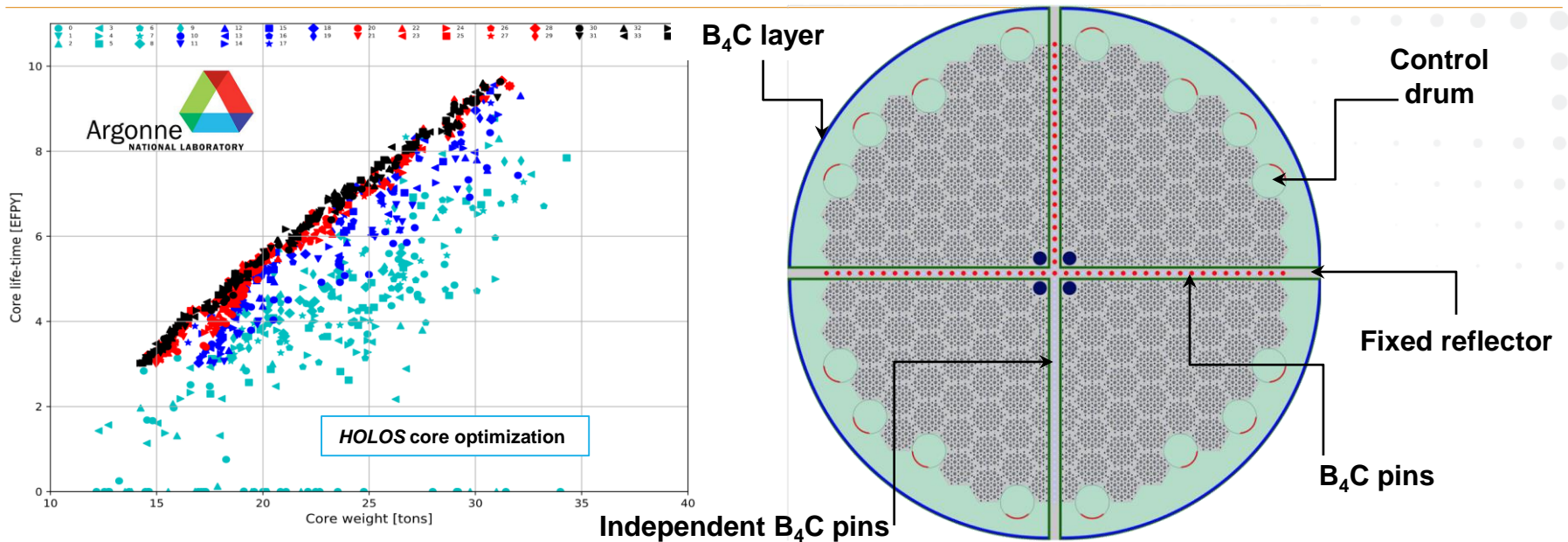
► Argonne National Laboratory (ANL)

- *Design Team (DT): Neutronics/core and shielding optimization*
- *Resource Team (RT): Thermal-hydraulic closed-loop Brayton cycle optimization and high-fidelity Techno-Economic Analysis (TEA)*
- *HolosGen: HOLOS QUAD configuration design optimization and testing*
- *ROMAC (Rotating Machinery and Controls Laboratory) UVA: HOLOS magnetic bearings*
- *ThermaDynamics Rail (TDR): Subscale simulator design, manufacturing, assembly and testing*

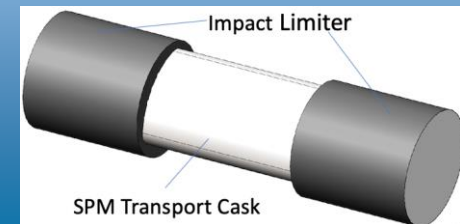


Completed Feasibility Analyses

Accomplishments

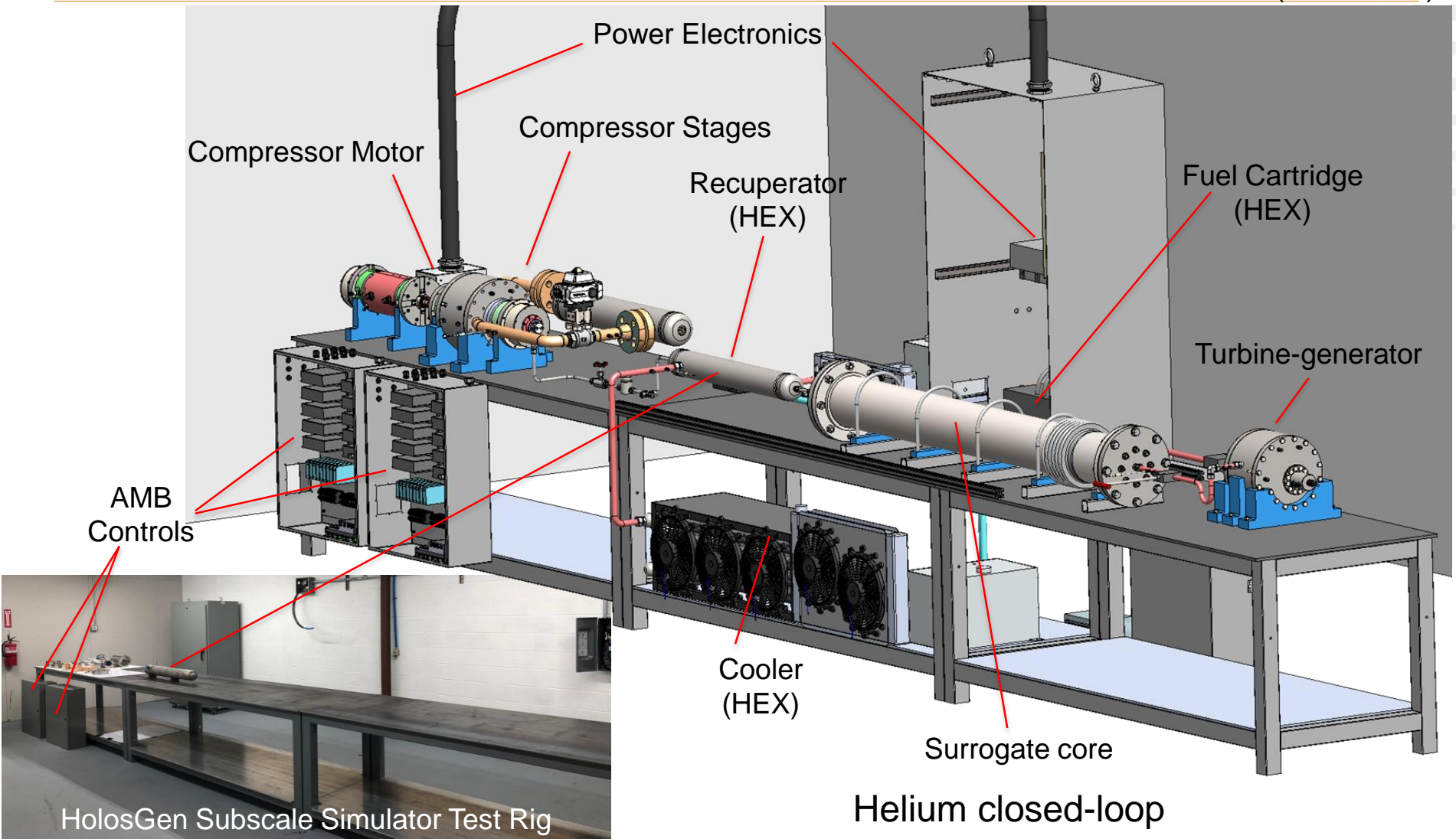


- ANL DT completed preliminary core design of the Holos-Quad configuration. Results successfully demonstrate performance and shutdown margins
- ANL RT completed
 - thermal-hydraulic evaluation of the Holos-Quad operated at 850°C. Results show $\eta > 40\%$
 - internal components shielding evaluation
 - shield-prefabricated building evaluation
 - shielding evaluation of spent SPMs for transport



Subscale Simulator Construction

Accomplishments (continued)



Complete Subscale Simulator

Future Plans

Remaining key challenges:

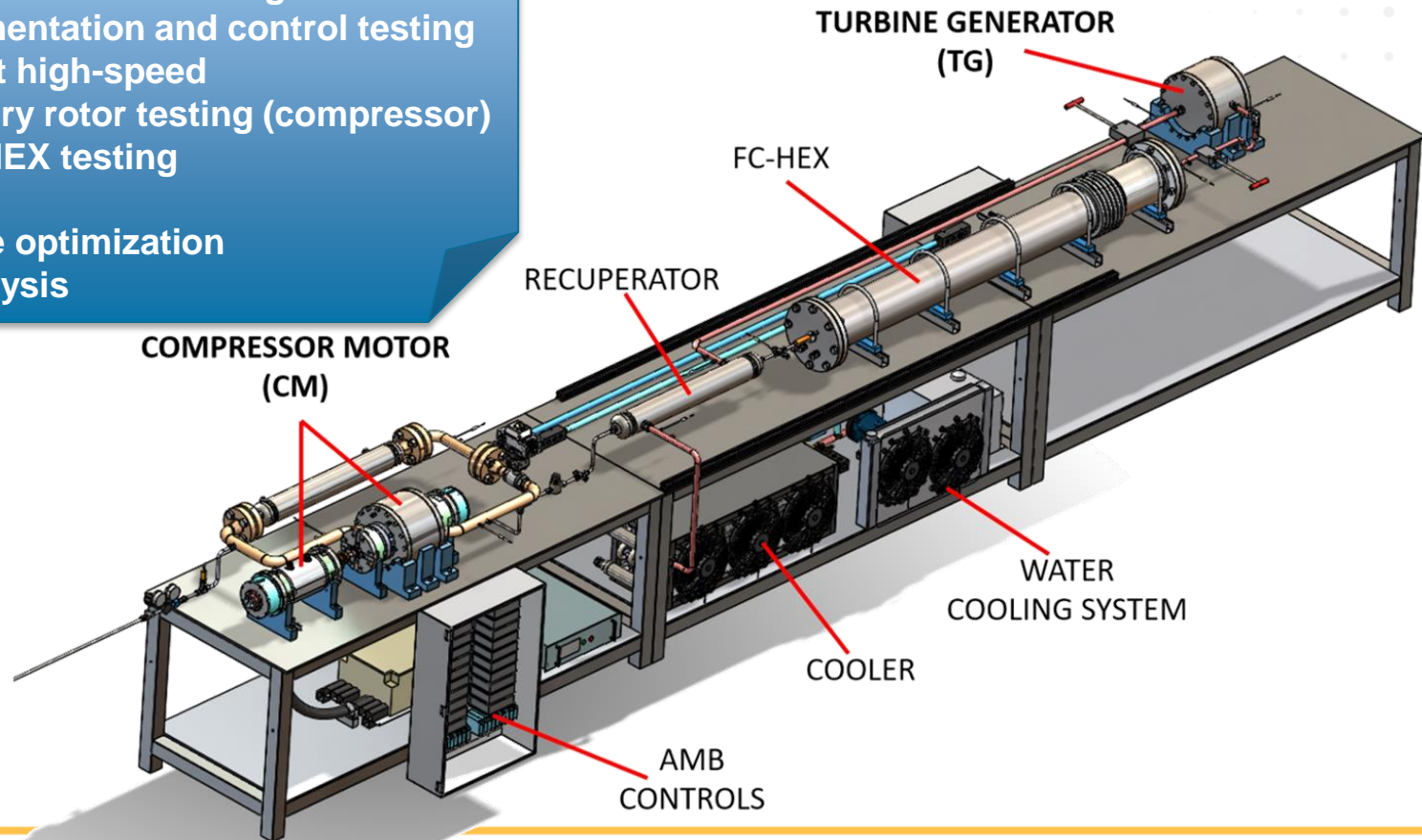
Subscale Simulator

- Complete helium loop
- Operate at full-scale pressure
- Execute core transients testing
- Digital instrumentation and control testing
- AMB testing at high-speed
- Turbomachinery rotor testing (compressor)
- Recuperator HEX testing

Full-scale Design

- Complete core optimization
- Transient Analysis

Subscale simulator with full-scale axial compressor stage



- Report published: N. Stauff, C. Lee, P. Shriwise, Y. Miao, R. Hu, P. Vegendla, T. Fei, “*Neutronic Design and Analysis of the Holos-Quad Concept*,” ANL/NSE-19/8, June 5, 2019. (<https://publications.anl.gov/anlpubs/2019/06/152914.pdf>)
- PHYSOR 2020 - submitted papers: 1) Nicolas E. Stauff, C. H. Lee, A. Wells, C. Filippone, “*Design Optimization of the Holos-Quad Micro-Reactor Concept*,” proceedings of PHYSOR, March 29-April 2, 2020. 2) Nicolas E. Stauff, P. Shriwise, C. H. Lee, A. Wells, C. Filippone, “*Neutronic Benchmark on Holos-Quad Micro-Reactor Concept*” proceedings of PHYSOR, March 29-April 2, 2020.
- Industrial partners engaged: High-maturity negotiations with Engineering Management firms and Manufacturers
- Design safety documentation in process: NRC safety evaluation of hazards and events which could challenge the safety of the design (support to Integrated Safety Analysis – ISA)
- Discussions with clients for different applications in progress
- Discussions with investors in progress

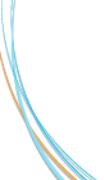
What advice would you give new teams?

Feedback

- Ensure you plan adequate resources to fully support administrative and legal tasks (confidentiality, CRADA, IP issues) as budget figures associated with these items are usually underestimated
- If possible try to have two managers sharing handling of reporting and monitoring schedule, as well as engineering and budget burn-rate to ensure continuity throughout the project (takes time and resources to train or update replacement managers)
- Our project is substantially complex: It encompasses all of the aspects enabling a nuclear reactor to safely generate electricity from thermal generation to connection to grid. Director Rachel Slaybaugh and ARPA-E teams managed to provide professional support in real-time and demonstrated remarkable ability to resolve unforeseen issues typical of highly innovative technologies. Thanks to their support the project is on schedule. These ARPA-E teams can transform innovative ideas into feasible tasks and bring very complex projects to success.

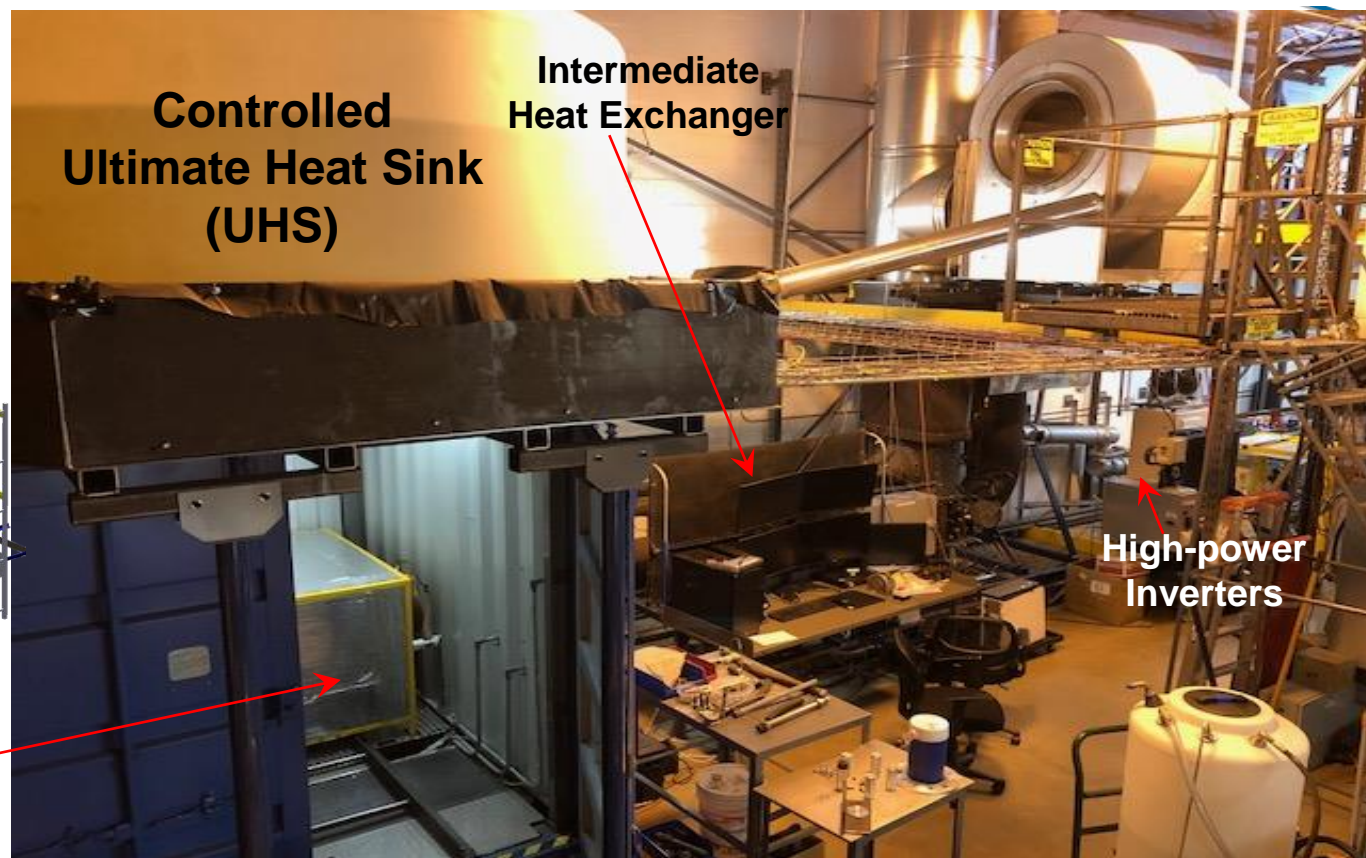
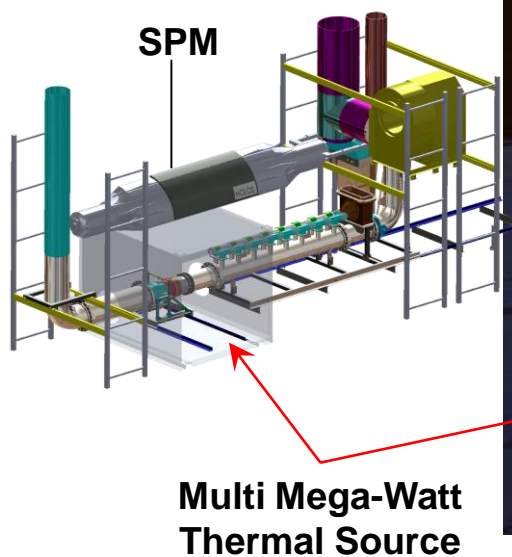
- ✓ *HOLOS QUAD* full-scale NOAK design with average outlet core temperature at 850°C demonstrated feasibility under key categories: neutronics, thermal-hydraulics, shielding, and costing
- Future NOAK design optimization include core optimization, transient analyses and load-following performance
- Subscale closed-loop simulator construction on schedule
- Additional work being conducted in parallel to the ARPA-E MEITNER project in 2020-21 (e.g., via GAIN) which benefits all HTGR developers includes:
 - SiC sleeves and shell performance assessment (high-temperature, high-pressure operations): ANL-HolosGen
 - Advanced coolant and moderator enclosure solution for micro gas cooled reactors with enhanced efficiency and safety: ANL-HolosGen
 - Evaluation of semi-autonomous passive control system for HTGR type special purpose reactors: University of Michigan-HolosGen
- FOAK full-scale SPM testing to support regulatory review of DBA, BDBA scenarios can be completed in 3 years with non-nuclear testing enabled by an operational multi MW test rig
- Looking forward to demonstrate *HOLOS QUAD* performance

Backup Slides



CHANGING WHAT'S POSSIBLE

HOLOS multi-MW thermal-hydraulic facility



Testing at full-scale conditions (1X SPM = **5.5 MWT**)

Low-cost safety and technical performance validation, supports and accelerate licensing processes

Holos Concept: Microreactor architecture scalable to 100 MWe

**61 MWe
SCALED UP FOUR SUBCRITICAL
TITAN POWER MODULES
INSIDE 4 ISO CONTAINERS**

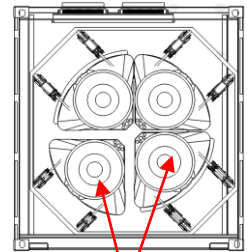
**AUXILIARY POWER
COMPONENTS
INSIDE 4 ISO CONTAINERS**

ORC MODULES



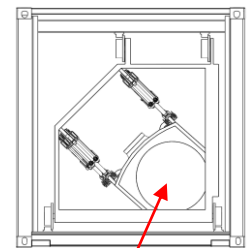
Video Clip

**1x
ISO container**



SPMs

**4x
ISO containers**



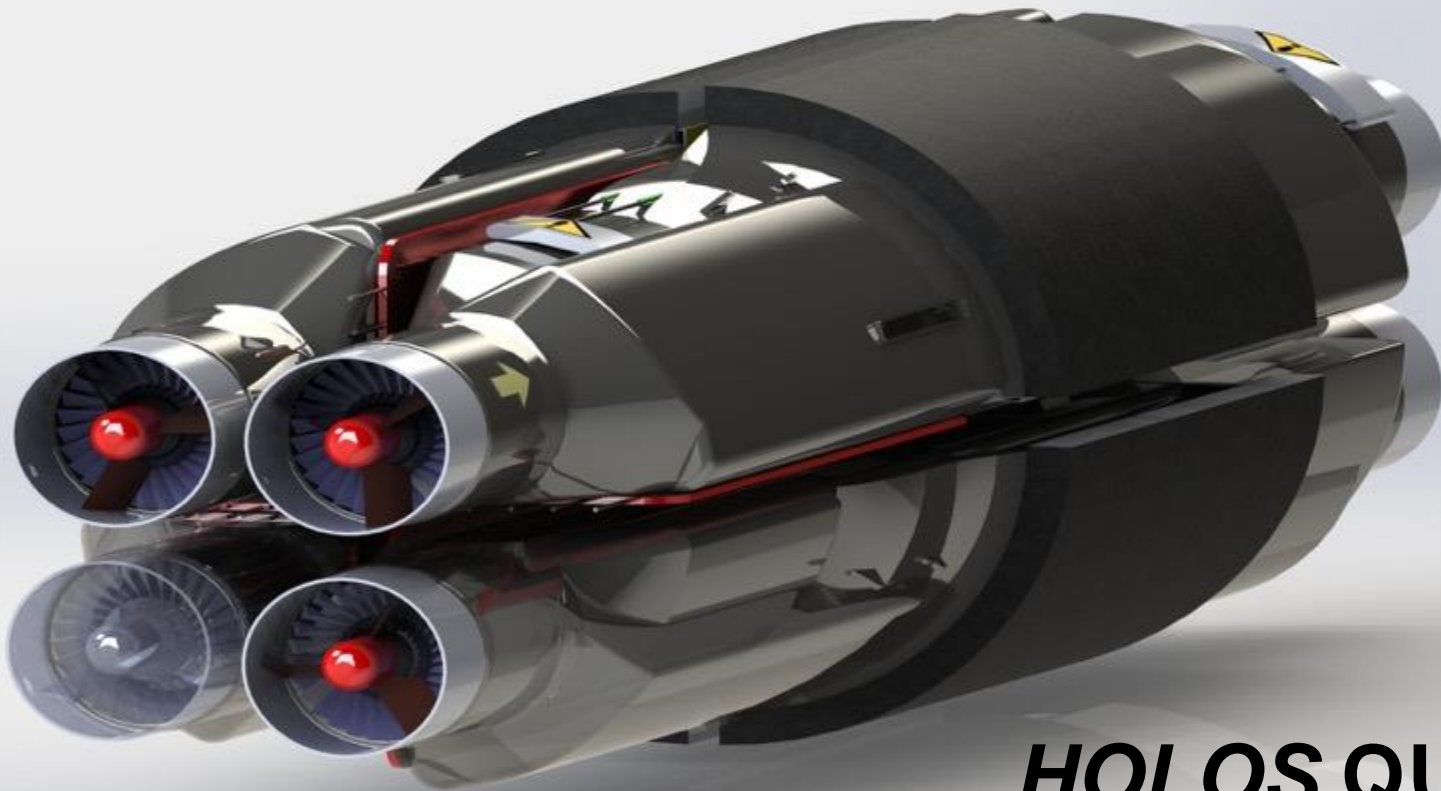
SPM

<http://www.holosgen.com/holos-titan-generator/>

<http://www.holosgen.com/open-to-closed-loop-technology/>

Thank you

QA & Discussion



HOLOS QUAD